LGN 5822 - Biometrical Genetics

L06 – Principles Experimental Design

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Introduction

The Experimentation

- The experimentation is a science that offers probabilistic support to the researcher and allows make inferences about the behavior of different natural phenomena, with a degree of uncertainty (margin error) known

Introduction

Importance of Experimentation

- Experimentation makes it possible to collect data in a structured and accurate way, reducing errors and bias in agronomic research
- This increases the reliability of the results

Introduction

Importance of Experimentation

Agronomic research is based on experiments

Introduction

Importance of Experimentation

- The researcher needs knowledge of experimental technique for

Introduction

Importance of Experimentation

- There is a relationship of experimentation with the scientific method

Introduction

Relationship of experimentation with the scientific method

(1) Identify a research problem

(2) Carefully define the problem

(3) Establish clear and precise objectives

(4) Formulate a working scientific hypothesis

(5) Collection of experimental data with quality and efficiency

(6) Analyze the collected data and interpret the results

(7) Report the results obtained with discussion and conclusions

Motivation

Important Questions

- Which experimental design best suits my goals?
- Does the order in which I handle my lab samples is important?
- How can I fit a proper statistical model to my data?
- How many replicates should I use?
- What sources of variation do I need to consider?

Motivation

Goals

- Aims
- Analysis
- Efficiency

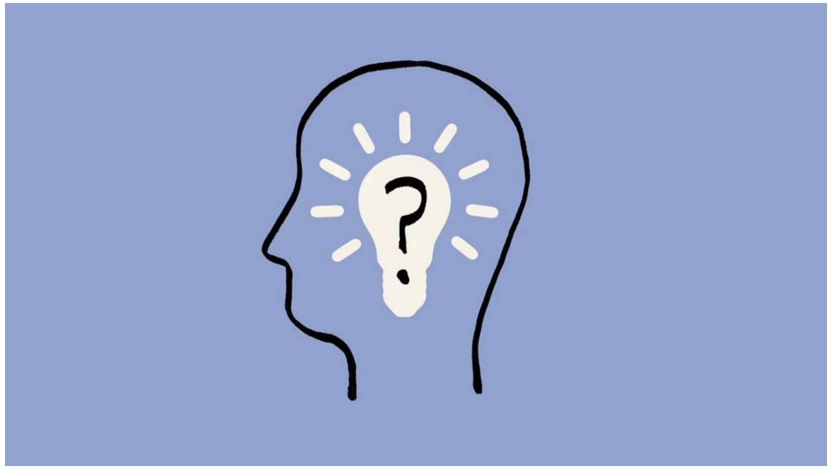
Motivation

“Failing to plan is planning to fail”

Benjamin Franklin

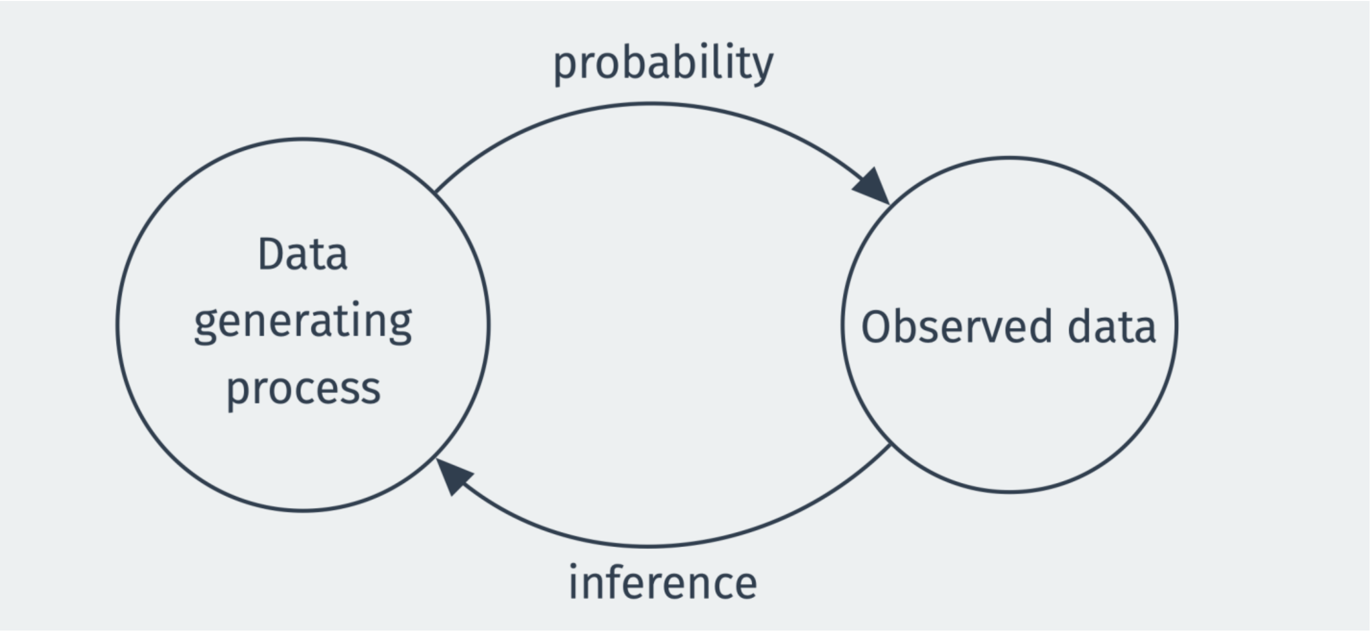
Experimentation

- Goal is to answer one or more specific questions
- Experiments are conducted to measure treatment differences or to test hypotheses



Experimentation

- Rules used to draw samples from the population of interest
- Population being sampled = inference of the experiment



Experimentation

Principles of Experimental Design

- General guidelines that aid in designing valid and precise experiments
    - Precisely estimated means
    - Absence of bias

Experimentation

Experimental designs

- The plan used in experimentation, which defines how treatments will be assigned to experimental units (plots)

- They are associated with statistical models that will be used in the statistical analysis of data collected in experiments

Field plots in use

Experimentation

Experimental designs

- One of the main objective of using experimental designs is to make it possible to estimate and minimize the effect of error variance

- The smaller the **variance of the error**, the greater the **precision and accuracy** of the experiments will be and, consequently, the greater the **efficiency and effectiveness** of agronomic research

Experimentation

Experimental designs

- Completely Randomized Design (DIC)
- Randomized Complete Block Design (RCBD)
- Incomplete Block Designs (IBD)
- Latice Designs (LD)
- Augmented Designs (AD)

Experimentation

Treatment or factor

- The element or material whose effect we want to measure, evaluate or compare in an experiment

- Will be tested or applied in an experimental study

Experimentation

Treatment or factor

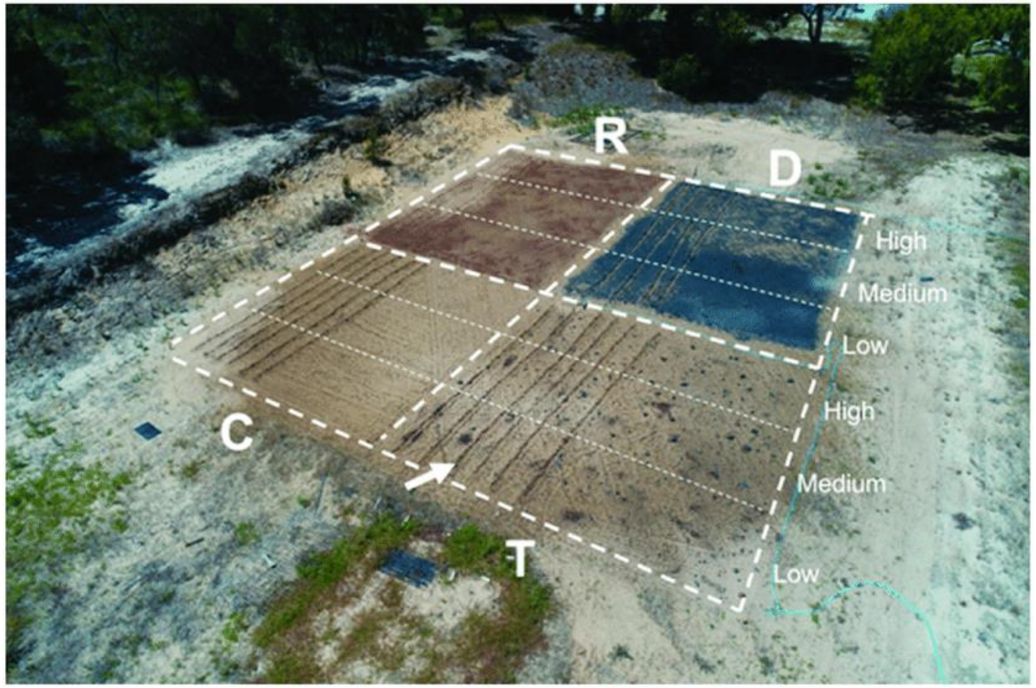
- **Random Effects:** Levels are random samples of a population; inference is valid for the population; *information between levels affects the estimation of each level*

- **Fixed Effects:** Levels are constant; levels are chosen; **inference is valid for the levels under study**; *information between levels does not affect the estimation of each level*

Experimentation

Experimental unit (Experimental plot)

The unit of material that will receive the treatment and provide the data that should reflect its effect



Correct choice of shape and size to minimize experimental error

Experimentation

Experimental unit (Experimental plot)

It depends:

- Material used and the amount of material available
- Research objectives
- Cost and number of treatments
- Type of management used

Minimum required size for obtaining measures with sufficient precision

Experimentation

Experimental Error

- It is a measure of variation due to various sources of variability that cannot be completely controlled or eliminated in an experiment (units that received the same treatment)

- Careful experimentation is important to **reduce experimental error** and **increase statistical power**

Experimentation

Inferences

- Inferences about possible treatment differences depend on the units to which treatments were applied

Experimentation

Basic Principles of Experimentation

The

Design of Experiments

By

Sir Ronald A. Fisher, Sc.D., F.R.S.

Honorary Research Fellow, Division of Mathematical Statistics, C.S.I.R.O., University of Adelaide; Foreign Associate, United States National Academy of Sciences; and Foreign Honorary Member, American Academy of Arts and Sciences; Foreign Member of the Swedish Royal Academy of Sciences, and the Royal Danish Academy of Sciences and Letters; Member of the Pontifical Academy; Member of the German Academy of Sciences (Leopoldina); formerly Galton Professor, University of London, and Arthur Balfour Professor of Genetics, University of Cambridge.

Fisher, Ronald Aylmer. "The design of experiments." *The design of experiments.* 1st Ed (1935).

Experimentation

Basic Principles of Experimentation

- Essential for validating results!

Experimentation

Replication

Definition

- The application of the same treatment to two or more experimental units in the same experiment

Experimentation

Replication

- Increasing the number of repetitions is one of the most efficient procedures for improving the accuracy and precision of a experiment

Experimentation

Replication

- Main functions of replication:
  - Increasing the precision of estimated means
  - Increasing the power of statistical tests
  - Providing an estimate of experimental error

Experimentation

Replication

The number of repetitions is a function of:

- Number of treatments
- Type of material experimental
- Cost of the experiment (materials, equipment, procedures and methods)
- Availability of physical space and labor
- Desired level of precision

It's almost impossible to determine the exact number of repetitions needed for a particular experiment (It depends!)

Experimentation

Replication

The number of repetitions is a function of:

- Degree of precision required
  - Size of treatment differences that need to be detected

- Sensitivity or recall: probability of correctly detecting positives, *i.e.*, correctly rejecting false null hypotheses
  - Smaller σ^2 or larger n results in greater sensitivity

Experimentation

Replication

- General rule (Tip)!
  - Have at least 10 degrees of freedom to the experimental error of any experiment

  - The reduction in size plot allows for greater number of plots (replications), aim to increase the precision of the experiment

Experimentation

Replication

Precision of Estimated Means

If $var(y_i) = \sigma^2$, then $var(\bar{y}) = {}^{\sigma^2}/_{n}$ where n is the number of replicates

Replication

Precision of Estimated Means

- More replicates result in more precisely estimated population means

- If the number of treatments and replications is large, there may be problems with data collection, such as area availability or sample homogeneity

Replication

Power of Statistical Tests

- Power also depends on $var(\bar{y}) = {}^{\sigma^2}/_{n}$

- The treatment difference may or may not be detected as statistically significant depending on the number of replicates
    - The smaller this variance, the more accurate the estimate of the sample mean will be in relation to the population mean

Experimentation

Replication

Pooling

- Combining multiple experimental units to obtain a single observation
- Pooling data from multiple experiments to perform joint analyzes

Experimentation

Replication

Pooling

- This changes the experimental unit to the pool of subjects
  - Experimental error is reduced
  - Degrees of freedom are based on the number of pools, not the number of subjects

Experimentation

Local Control

Definition

- Stratification (grouping) of experimental units (locals or materials) into homogeneous groups called blocks

Experimentation

Local Control

- Better estimation and more adequate control of experimental error

- It prevents against the detrimental effects of environmental variations within the experimental area

- If homogeneity between experimental units is an issue, the experiment can be subdivided to increase efficiency

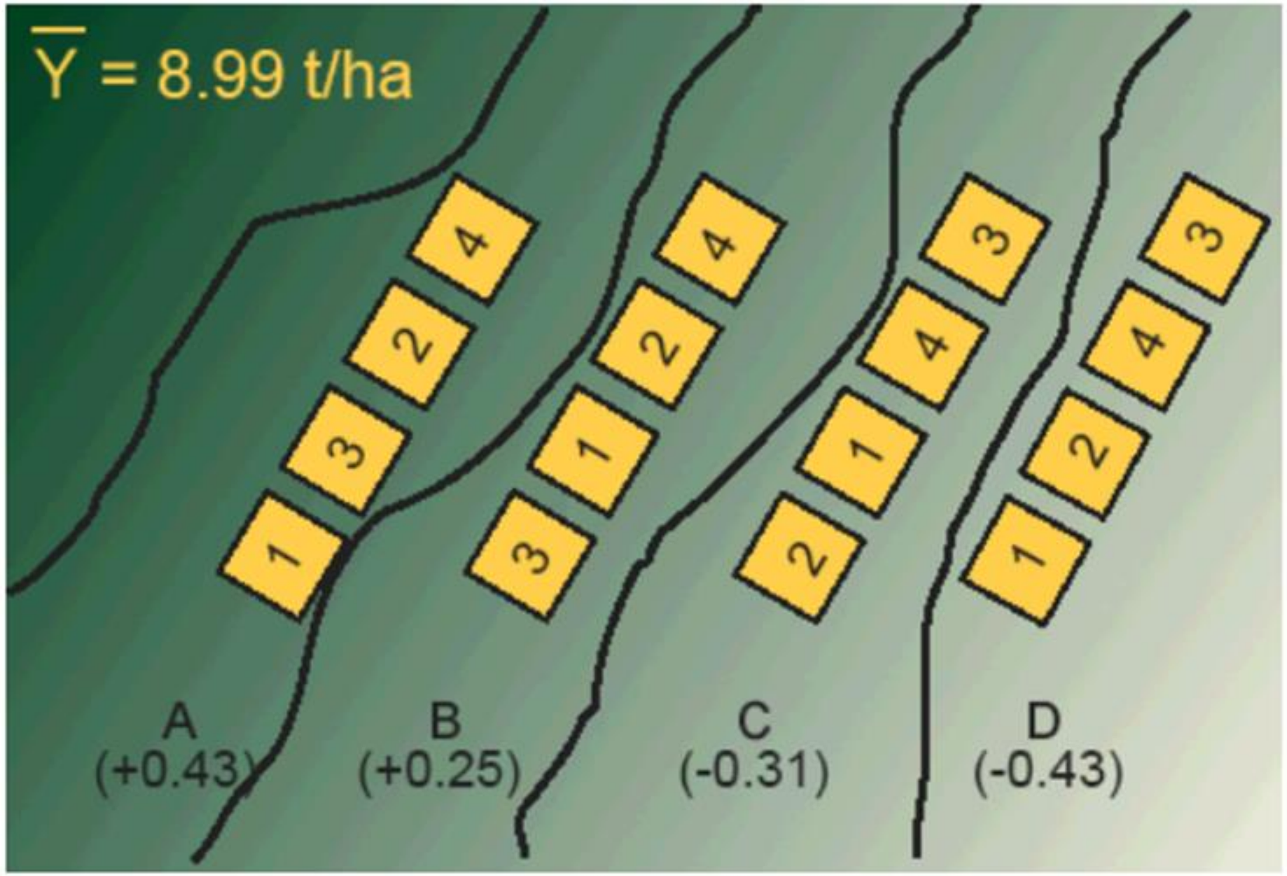
Local Control

- A common form of local control is to divide the experimental area in *blocks*, such that experimental units in each block are homogeneous

- Blocks may be complete, if each block includes all treatments, or be further subdivided in incomplete blocks; they may be balanced or partially balanced

Experimentation

Local Control



Experimentation

Local Control

Experimental Precision

- The grouping of experimental units into blocks makes the **variation within the block smaller than the variation between blocks**

- This **usually** increases the precision of the experiment

Experimentation

Local Control

- It is not uncommon for blocks to be called replicates: be careful with the precise meaning
  - **Blocks**: Group of experimental units that are similar to each other with respect to some specific characteristic that can affect the result of the experiment
  - **Replications**: These are individual experimental units within a block that receive the same treatment

Experimentation

Local Control

Choice of Design

- Designs should be as simple as possible, while appropriately controlling the experimental error and providing enough precision

Experimentation

Randomization

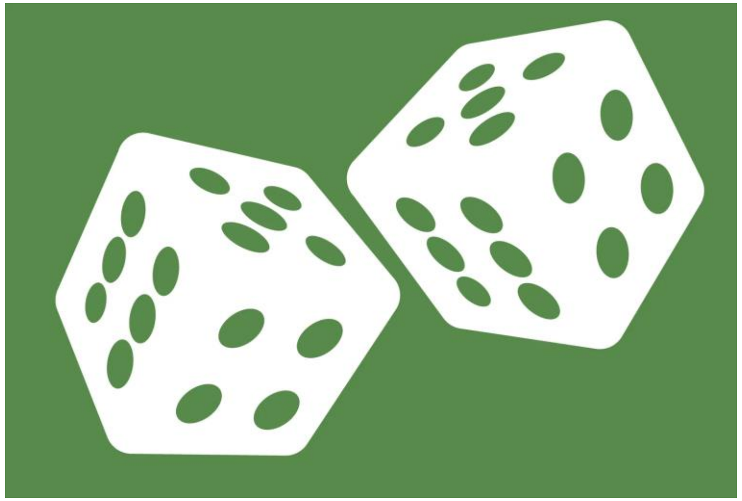
Definition

- Randomization is the random assignment of treatments, such that all treatments have the same chance of being assigned to a given experimental

No treatment is consistently favored or prejudicated!

Randomization

- It has the function of ensure that the estimate of experimental error and treatment effects is bias free



Experimentation

Randomization

- Main functions of randomization:
  - Ensures that treatments are causally affected by unknown sources of variation
  - Allows errors (deviations) to become random
  - Allows errors associated with treatments independent of each other, thus allowing the application of statistical tests

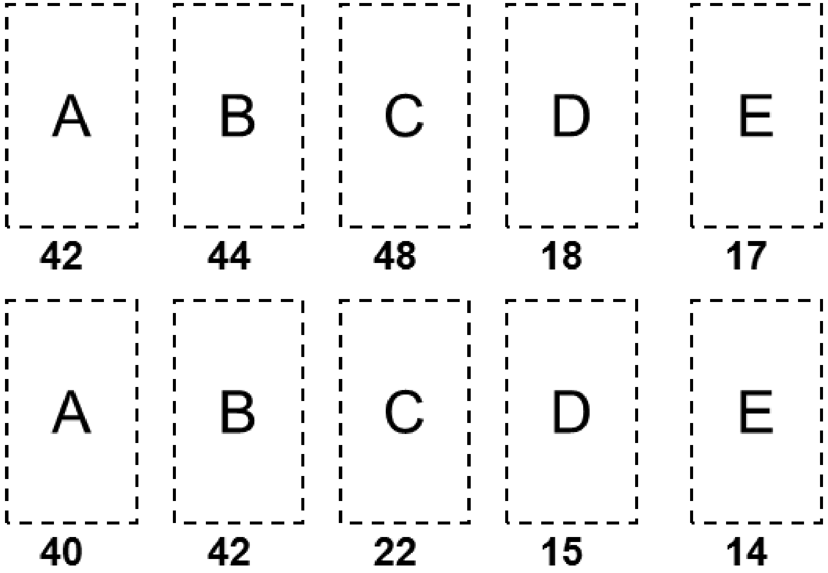
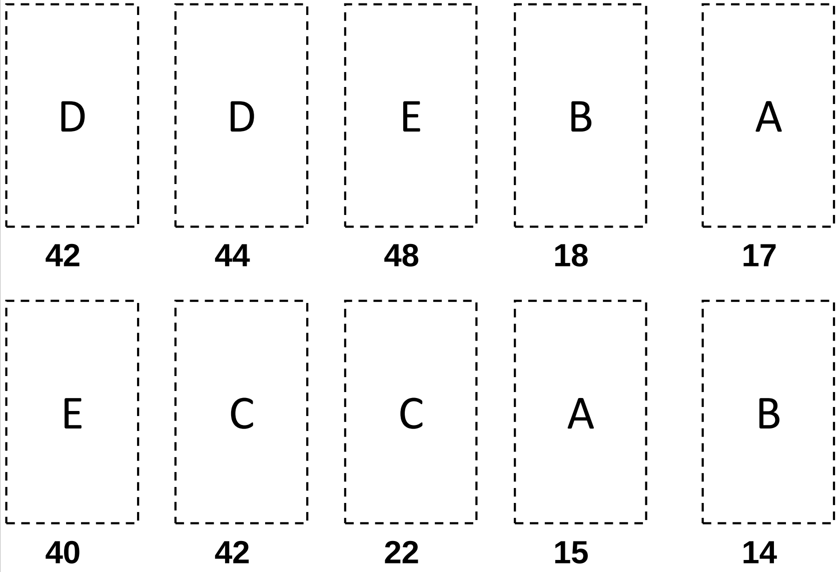
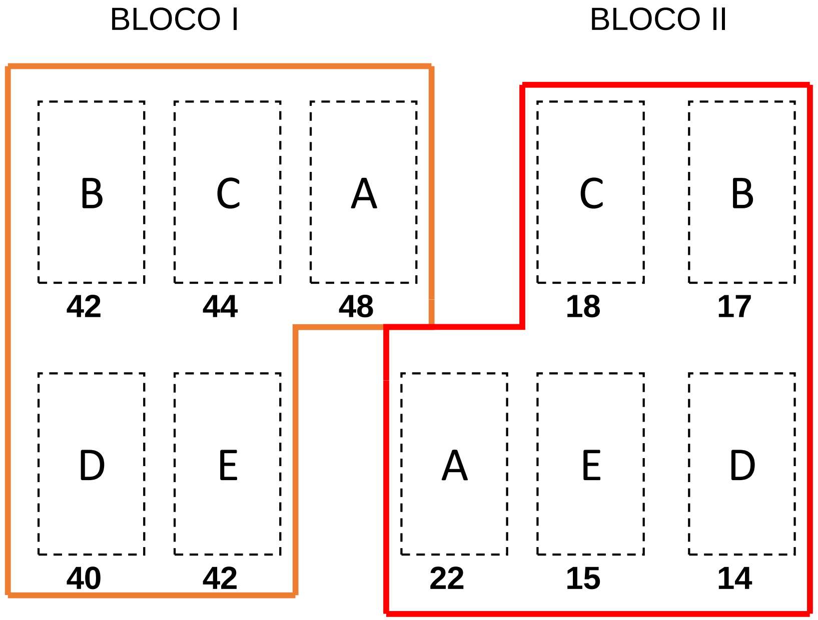
In other words, it makes an experiment valid!

Experimentation

Randomization

- Randomization removes systematic correlation among errors
- Remember that hypothesis tests often assume that residual errors are independent!

Experimentation

Replication	Randomization	Local Control
		

References

Chapter 6 - Principles of Experimental Design[1]

Chapter 1 - Basics[2]

- 1. Steel, R. G. & Torrie, J. H. Principles and Procedures of Statistics: A Biometrical Approach. 2nd Edition. (1980)

- 2. Casella, G. Statistical Design. (2008)